NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1756

ULTIMATE STRESSES DEVELOPED BY 24S-T AND

ALCLAD 75S-T ALUMINUM-ALLOY SHEET IN

INCOMPLETE DIAGONAL TENSION

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SUMMARY

Strength tests were made on 24S-T and Alclad 75S-T aluminum-alloy sheet in diagonal tension. These tests indicated that the ultimate shear stress was essentially independent of the rivet factor if the rivet factor was greater than 0.6, which covers most of the practical range. Curves showing the effect of diagonal tension on the ultimate shear stress in the gross section are presented. These curves supersede those given in NACA TN No. 1364.

INTRODUCTION

The strength of a shear web is frequently computed on the assumption that failure occurs when the shear stress in the net section between rivet or bolt holes reaches the ultimate shear stress of the material. The main difficulty with this procedure is to find a really satisfactory method of determining the ultimate shear stress of the material. Another difficulty is that stress concentration effects of holes may be encountered at ultimate load similar to those encountered in tension and these effects must be evaluated. When failure of the shear web occurs before buckling takes place, the shear load on the web is resisted by true shear stresses. If failure of the shear web occurs after buckling takes place, the stress condition in the web is very complicated; however, it is convenient in strength calculations to use as a reference value a fictitious shear stress computed on the assumption that the web did not buckle. It then becomes necessary to find a satisfactory method of determining a fictitious ultimate shear stress of a thin shear web which fails after buckling occurs and the relationship between the ultimate shear stress and the degree of development of buckling.

The most expedient method of determining the ultimate stresses for shear webs with rivet or bolt holes is by direct tests on shear webs fastened with rivets or bolts and subjected to a pure shear load. The stiffening of the webs should be varied in order to determine the relationship between the ultimate shear stress and the degree of development of diagonal tension. The ratio of pitch to diameter of the holes should also

be varied in order to evaluate the combined effect of reduction in section and stress concentration around the holes at ultimate load.

Results obtained by this type of test were given in reference 1 for webs which approached a condition of pure shear and for webs with partly developed diagonal tension. These tests indicated that, within the test scatter, the ultimate shear stress on the gross section is essentially independent of the ratio of net area to gross area along a line of holes if this ratio is greater than 0.6. These data were used in reference 2 to draw empirical curves showing the effect of the degree of development of diagonal tension on the allowable shear stress on the gross section. The present investigation is extended to webs with a greater degree of development of diagonal tension, and new curves showing the relationship between the degree of development of diagonal tension and the average ultimate shear stress on the gross section are presented. These curves supersede the empirical curves given in reference 2.

SYMBOLS

C_r rivet factor $\left(\dfrac{p - d}{p} \text{ or } \dfrac{\text{net area along line of holes}}{\text{gross area along line of holes}}\right)$

L   length along one side of shear panel between corner bolts, inches

P   load required to fail panel, kips

b   width of panel, between inside lines of bolts, inches

d   diameter of rivet or bolt holes, inches

k   diagonal-tension factor (see reference 2)

p   pitch of rivet or bolt holes in one row, inches

t   thickness of sheet, inches

σ_{ult} ultimate tensile stress, ksi

τ shear stress on web, ksi

τ_{cr} critical shear stress, ksi

τ_g shear stress on gross section of web, ksi

τ_n shear stress on net section of web between rivet holes, ksi

$\tau_{g_{av}}$ average measured gross shear stress at failure for specimens having the same value of k at failure, ksi

TEST SPECIMENS AND PROCEDURE

The test specimens were made from 24S-T or Alclad 75S-T aluminum
alloy. The effective length of all specimens was approximately 50 inches.
In order to have the specimens fail at different stages of incomplete
diagonal tension the following combinations of nominal web thickness and
width (in inches) between the inside line of bolts were used: 0.020 × ·5,
0.020 × 12, 0.025 × 6, 0.025 × 12, and 0.051 × 12. The actual dimensions
of all specimens tested in the present investigation, as well as those
described in reference 1, are included in tables 1 and 2. All specimens
were tested in a rectangular frame of the type shown in figure 1. The
load was applied at the center outer edge of the frame and caused essentially
pure shear load on the specimen. The bars connecting the two sides of the
frame were used to decrease the flexibility of the edge members on the long
side of the panel. The specimens were fastened in the frame with one or two
rows of bolts which were tight fits in the holes and had heavy washers under
the heads.

In all tests, the pitch of the holes was 1 inch and the hole diameters,
used to obtain a variation in pitch-diameter ratio, were 3/16, 1/4, 5/16,
and 3/8 inch.

The test specimens were cut from several different sheets of material.
Ultimate tensile stresses of each sheet of material were determined from
two standard tensile specimens cut parallel to the grain and two standard
tensile specimens cut perpendicular to the grain.

TEST RESULTS

The results obtained in the present investigation, as well as data
obtained from reference 1, are presented in tables 1 and 2.

The shear stress at failure was computed for both the gross section
and the net section along the line of holes. The shear stress at failure
in the gross section was computed by the formula

$$\tau_g = \frac{P}{Lt} \tag{1}$$

The shear stress at failure in the net section along the line of holes
was computed by the formula

$$\tau_n = \frac{\tau_g}{C_r} \tag{2}$$

A comparison of specimens cut from different sheets of the same material was made possible by reducing all shear stresses computed by formulas (1) and (2) to correspond to an ultimate tensile stress of 62 ksi for 24S-T aluminum alloy and 72 ksi for Alclad 75S-T aluminum alloy. This reduction was accomplished by multiplying the shear stress obtained from formulas (1) and (2) by $62/\sigma_{ult}$ for 24S-T aluminum alloy and by $72/\sigma_{ult}$ for Alclad 75S-T aluminum alloy, where σ_{ult} is the lowest value of the actual tensile strength of a particular sheet obtained from two standard tensile specimens cut perpendicular to the grain and two standard tensile specimens cut parallel to the grain of the sheet. The lowest values of the tensile strength were used because reference 3 states that specimens cut from the sheet in any direction shall possess certain minimum properties not below the standard given in reference 3. The ultimate tensile strength in one direction was never more than 4.5 percent below that for the other direction.

The reduced values of τ_g and τ_n are shown in figures 2 and 3. These figures also show the average gross shear stress at failure $\tau_{g_{av}}$ for each group of similar specimens. In most of the tests τ_g was within 10 percent of $\tau_{g_{av}}$.

DISCUSSION OF RESULTS

Variations in shear stress with C_r.- A previous investigation (reference 1) on a large number of 24S-T aluminum-alloy shear webs with k approximately 0.02 and 0.35 and Alclad 75S-T aluminum-alloy shear webs with k approximately 0.06 and 0.40 indicated that the ultimate shear stress on the net section was not constant (as is usually assumed) but decreased as the rivet factor C_r increased. This result was generally confirmed by the tests of the present investigation which were made at values of k of approximately 0.55 and 0.72 for 24S-T aluminum alloy and k of approximately 0.59 and 0.74 for Alclad 75S-T aluminum alloy. This decrease in the ultimate shear stress on the net section as C_r increased can be accounted for partly by the increase in stress-concentration effects and partly by an increase in the bearing stresses at the holes. Sufficient data are not available to determine the exact interaction effect between the shear stresses and the bearing stresses.

The stresses τ_g shown in figures 2 and 3 are usually within 10 percent of $\tau_{g_{av}}$. In the tests of reference 1 τ_g was within 9 percent of $\tau_{g_{av}}$. In the tests on the 24S-T webs with k = 0.72 a definite decrease in τ_g occurs as C_r decreases. This decrease is approximately equal to the increase in τ_n as C_r decreases; therefore, a constant value of either τ_g or τ_n could be used for this group of webs. This relatively small group of webs is the only group, however, which shows a definite decrease in τ_g as C_r decreases.

Some of the variation in the ultimate shear stresses on the gross section may have been caused by friction between the web and the frame. A preliminary investigation indicated that if the bolts were drawn very tight the effect of this friction could be very large. Most of this friction effect was eliminated in the present tests and in the tests of reference 1 because the bolts were drawn just tight enough to bring the frame and the web together.

Ultimate shear stresses.- The curves in figure 4 show the relationship between the shear stresses in the gross section at failure and the diagonal-tension factor k. These curves are based on the values of $\tau_{g_{av}}$ given in figures 2 and 3 of the present paper and figures 4 and 5 of reference 1. The upper curves show the average ultimate shear stress for shear webs which are not allowed to buckle at the edges of the holes. This condition is satisfied if the edge of the shear web is between two heavy plates or has heavy washers on one side and a heavy plate on the other. Standard-size brass washers were used in the tests which served as a basis for the upper curve. The lower curve in figure 4 shows the average ultimate shear stress for shear webs which were allowed to buckle at the edge of the holes. No tests of this type are included in the present paper; however, such tests were included in reference 1 and these data indicated that the strength of a web which was allowed to buckle at the holes was about 11 percent less than the strength of a web which did not buckle at the holes. The lower curves apply to webs which have the heads of the rivets or bolts bearing directly on the sheet.

The curves in figure 4 are identical with the curves in figure 14 of reference 2 up to k ≈ 0.4. In this region both sets of curves are based on the tests presented in reference 1. For values of k higher than 0.4, the curves in figure 14 of reference 2 were based on an estimated value for k = 1.0, and they are slightly lower in this region than the curves in figure 4 which are based on experimental data obtained in the present investigation.

The curves in figure 4 are applicable to joints made with either one or two rows of bolts if the bearing stresses at the holes do not exceed the allowable bearing stresses given in reference 4. The tests of reference 1 indicated that if the bearing stresses do exceed the allowable bearing stresses given in reference 4, the allowable shear stresses will then be less than those shown in figure 4.

Comparison with other tests.- Figure 5 presents the results of tests from references 2 and 5 for comparison with the empirical curve for the shear stress in the gross section at failure. Most of the points for the beams of reference 2 are very close to the average curve. All points for the shear webs of reference 5 are above the average curve. These webs were bolted between heavy angles and the bolts were drawn tight. The increase in the ultimate stress was probably a result of the fact that some of the load was carried by friction between the shear web and the frame. This friction should usually not be relied upon to carry load under service conditions.

CONCLUDING REMARKS

Results of strength tests on a 24S-T and Alclad 75S-T aluminum-
alloy sheet in diagonal tension indicated that the ultimate shear stress
was essentially independent of the rivet factor in the practical range
(rivet factor greater than 0.6). Curves are presented showing the
effect of the diagonal tension on the ultimate shear stress in the gross
section. These curves supersede those given in NACA TN No. 1364.

Langley Aeronautical Laboratory
     National Advisory Committee for Aeronautics
          Langley Field, Va., September 24, 1948

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TABLE 1

DIMENSIONS, TEST DATA, AND RESULTS FOR

24S-T ALUMINUM-ALLOY SPECIMENS

Specimen	d (in.)	Rows of holes	t (in.)	b (in.)	L (in.)	τ_{or} (ksi)	P (kips)	τ_g (ksi)	$\dfrac{\tau_g}{\tau_{or}}$	k	σ_{ult} (ksi) (a)	τ_g (ksi) Corrected (b)	τ_n (ksi) Corrected (b)
							$k \approx 0.017$ (c)						
1	3/16	2	0.0409	5.0	51.25	31.6	72.50	34.85	1.100	0.020	69.60	31.05	38.20
2	3/16	2	.0413	5.0	51.25	31.6	72.76	34.60	1.095	.020	69.60	30.80	38.00
3	3/16	2	.0384	5.0	51.25	31.2	70.25	35.70	1.145	.030	70.07	31.60	38.90
4	3/16	1	.0414	5.0	51.25	31.6	71.00	33.60	1.062	.012	69.60	29.92	36.85
5	3/16	1	.0414	5.0	51.25	31.6	68.40	32.40	1.026	.002	69.60	28.85	35.50
6	1/4	2	.0391	5.0	51.25	31.2	70.00	34.90	1.120	.022	70.07	30.85	41.20
7	1/4	1	.0391	5.0	51.25	31.2	65.20	32.65	1.047	.012	70.07	28.90	38.50
8	1/4	1	.0412	5.0	51.25	31.6	72.00	34.30	1.085	.018	69.60	30.55	40.70
9	1/4	1	.0413	5.0	51.25	31.6	72.70	34.50	1.092	.020	69.60	30.70	40.90
10	1/4	1	.0413	5.0	51.25	31.6	69.10	32.70	1.035	.008	69.60	29.10	38.90
11	1/4	1	.0385	5.0	51.25	31.2	65.40	33.15	1.063	.012	70.07	29.30	39.10
12	5/16	2	.0384	5.0	51.25	31.2	66.20	33.65	1.079	.016	70.07	29.75	43.30
13	5/16	1	.0391	5.0	51.25	31.2	67.40	33.65	1.079	.016	70.07	29.75	43.30
14	5/16	1	.0412	5.0	51.25	31.6	72.00	34.30	1.085	.018	69.60	30.55	44.30
15	5/16	1	.0407	5.0	51.25	31.6	68.80	33.10	1.048	.012	69.60	29.50	42.80
16	3/8	2	.0390	5.0	51.25	31.2	68.60	34.40	1.102	.020	70.07	30.42	48.70
17	3/8	1	.0396	5.0	51.25	31.3	69.00	34.00	1.087	.018	70.07	30.10	48.20
18	3/8	1	.0408	5.0	51.25	31.6	71.80	34.50	1.092	.020	69.60	30.72	49.20
19	3/8	1	.0412	5.0	51.25	31.6	72.80	34.70	1.098	.020	69.60	30.90	49.30
							$k \approx 0.35$						
20	3/16	2	0.0411	5.0	51.25	5.62	65.9	31.4	5.59	0.36	69.6	28.0	34.5
21	3/16	2	.0407	5.0	51.25	5.51	64.4	31.0	5.62	.35	69.6	27.5	33.9
22	3/16	2	.0390	5.0	51.25	5.07	61.8	31.0	6.11	.37	70.1	27.4	33.8
23	3/16	1	.0414	5.0	51.25	5.71	62.4	29.5	5.17	.34	69.6	26.3	32.5
24	3/16	1	.0413	5.0	51.25	5.70	62.7	29.7	5.22	.34	69.6	26.5	32.5
25	3/16	1	.0413	5.0	51.25	5.70	58.1	27.6	4.84	.33	69.6	24.6	30.2
26	1/4	2	.0392	5.0	51.25	5.12	58.5	29.1	5.69	.36	70.1	25.7	34.4
27	1/4	1	.0389	5.0	51.25	5.03	59.3	29.8	5.92	.37	70.1	26.3	35.1
28	1/4	1	.0408	5.0	51.25	5.55	60.1	29.0	5.22	.34	69.6	25.8	34.3
29	1/4	1	.0413	5.0	51.25	5.70	59.3	28.1	4.93	.33	69.6	25.1	33.4
30	5/16	2	.0391	5.0	51.25	5.09	58.1	29.0	5.69	.36	70.1	25.7	37.3
31	5/16	1	.0385	5.0	51.25	4.93	58.4	29.7	6.02	.37	70.1	26.2	38.1
32	5/16	1	.0412	5.0	51.25	5.64	61.1	29.1	5.17	.34	69.6	25.9	37.7
33	5/16	1	.0413	5.0	51.25	5.70	59.4	28.2	4.95	.33	69.6	25.1	36.6
34	3/8	2	.0384	5.0	51.25	4.91	54.8	27.9	5.68	.36	70.1	24.7	39.5
35	3/8	1	.0389	5.0	51.25	5.03	55.3	27.7	5.51	.35	70.1	24.5	39.3
36	3/8	1	.0410	5.0	51.25	5.59	58.6	28.1	5.03	.34	69.6	25.1	39.9
37	3/8	1	.0406	5.0	51.25	5.48	57.2	27.7	5.05	.34	69.6	24.7	39.4
							$k \approx 0.55$						
38	3/16	2	0.0264	6.0	49.63	1.61	37.2	27.4	17.0	0.55	70.2	24.3	29.9
39	1/4	2	.0265	6.0	49.63	1.61	39.5	30.0	18.6	.56	70.2	26.5	35.4
40	1/4	1	.0261	6.0	49.63	1.61	39.1	30.1	18.7	.56	70.2	26.6	35.6
41	5/16	1	.0263	6.0	49.63	1.61	37.2	28.4	17.6	.55	69.7	25.3	36.8
42	3/8	1	.0265	6.0	49.63	1.61	35.0	26.6	16.5	.54	69.7	23.7	37.9
							$k \approx 0.72$						
43	3/16	2	0.0265	12.0	49.63	0.403	38.5	29.2	72.5	0.73	70.2	25.8	31.8
44	1/4	2	.0262	12.0	49.63	.403	35.8	27.5	68.1	.72	69.7	24.4	32.7
45	1/4	1	.0263	12.0	49.63	.403	36.4	27.8	69.0	.72	69.7	24.7	33.0
46	5/16	1	.0264	12.0	49.63	.403	34.4	26.2	65.0	.72	70.2	23.1	33.8
47	3/8	1	.0262	12.0	49.63	.403	33.5	25.7	63.8	.72	70.2	22.7	36.4

[a] Actual tensile strength of material.
[b] Stresses corrected to $\sigma_{ult} = 62$ ksi.
[c] These specimens had heavy stiffener dividing them into panels 1 inch by 5 inches. (See fig. 1, reference 1.)

TABLE 2

DIMENSIONS, TEST DATA, AND RESULTS FOR

ALCLAD 75S-T ALUMINUM-ALLOY SPECIMENS

Specimen	d (in.)	Rows of holes	t (in.)	b (in.)	L (in.)	τ_{cr} (ksi)	P (kips)	τ_g (ksi)	$\frac{\tau_g}{\tau_{cr}}$	k	σ_{ult} (ksi) (a)	τ_g (ksi) Corrected (b)	τ_n (ksi) Corrected (b)
						$k \stackrel{\sim}{\underset{(c)}{\approx}} 0.057$							
1	3/16	2	0.0390	5.0	51.25	31.2	77.6	38.8	1.24	0.050	78.6	35.6	43.8
2	1/4	2	.0390	5.0	51.25	31.2	81.0	40.6	1.30	.058	78.6	37.2	49.6
3	1/4	1	.0393	5.0	51.25	31.2	81.0	40.3	1.29	.058	78.6	36.9	49.2
4	5/16	2	.0390	5.0	51.25	31.2	83.6	41.8	1.34	.065	78.6	38.3	55.7
5	5/16	1	.0390	5.0	51.25	31.2	81.0	40.6	1.30	.058	78.6	37.2	54.1
6	3/8	2	.0390	5.0	51.25	31.2	78.6	39.3	1.26	.050	78.6	36.0	57.7
7	3/8	1	.0397	5.0	51.25	31.2	83.5	41.1	1.32	.060	78.6	37.6	60.2
						$k \approx 0.40$							
8	3/16	2	0.0390	5.0	51.25	5.05	73.6	36.9	7.30	0.41	78.6	33.8	41.5
9	1/4	2	.0383	5.0	51.25	4.88	66.8	34.1	6.98	.40	78.6	31.2	41.5
10	1/4	1	.0396	5.0	51.25	5.21	71.2	35.1	6.74	.39	78.6	32.1	42.8
11	5/16	2	.0390	5.0	51.25	5.05	69.0	34.6	6.85	.39	78.6	31.7	46.0
12	5/16	1	.0389	5.0	51.25	5.02	68.6	34.4	6.86	.39	78.6	31.5	45.9
13	3/8	2	.0386	5.0	51.25	4.98	68.1	34.5	6.92	.40	78.6	31.6	50.3
14	3/8	1	.0396	5.0	51.25	5.22	70.2	34.6	6.63	.39	78.6	31.7	50.8
						$k \approx 0.59$							
15	3/16	2	0.0201	5.0	51.25	1.39	35.4	35.5	25.6	0.61	79.6	32.1	39.5
16	3/16	2	.0205	5.0	49.68	1.42	36.0	35.4	25.0	.60	79.6	32.0	39.4
17	3/16	2	.0496	12.0	49.68	1.61	87.5	35.6	22.1	.58	79.9	32.1	39.5
18	3/16	2	.0500	12.0	49.68	1.61	82.1	33.1	20.5	.58	79.9	29.9	36.7
19	3/16	2	.0489	12.0	49.68	1.56	78.0	32.1	20.6	.58	78.9	29.3	36.1
20	3/16	2	.0242	6.0	49.68	1.61	42.4	35.2	21.8	.58	70.8	35.8	44.1
21	1/4	2	.0204	5.0	49.68	1.42	35.1	34.7	24.5	.60	79.6	31.3	41.7
22	1/4	2	.0203	5.0	49.68	1.42	38.1	37.8	26.7	.61	79.6	34.5	46.0
23	1/4	2	.0203	5.0	49.68	1.42	34.8	34.5	24.6	.60	79.6	31.2	41.6
24	1/4	1	.0239	6.0	49.68	1.61	37.8	31.8	19.7	.57	70.8	32.3	43.0
25	1/4	2	.0241	6.0	49.68	1.61	38.8	32.4	20.1	.57	70.8	32.9	43.9
26	1/4	2	.0489	12.0	49.68	1.56	75.7	31.2	20.0	.57	78.9	28.5	37.9
27	5/16	1	.0244	6.0	49.68	1.61	38.4	31.7	19.7	.57	68.8	33.1	48.2
28	5/16	1	.0202	5.0	49.68	1.42	35.0	34.9	24.6	.60	79.6	31.6	45.8
29	5/16	1	.0204	5.0	49.68	1.42	34.2	33.8	23.8	.60	79.6	30.6	44.4
30	5/16	1	.0204	5.0	49.68	1.42	39.0	38.5	27.2	.61	79.6	34.9	50.7
31	5/16	1	.0486	12.0	49.68	1.56	80.6	33.5	21.4	.58	78.9	30.6	44.4
32	5/16	1	.0491	12.0	49.68	1.56	91.6	37.7	24.1	.60	79.9	34.0	49.3
33	5/16	1	.0497	12.0	49.68	1.61	89.3	36.3	22.5	.59	79.9	32.7	47.6
34	5/16	1	.0493	12.0	49.68	1.56	83.0	33.9	21.7	.58	79.9	30.6	44.4
35	3/8	1	.0207	5.0	49.68	1.43	39.0	38.1	26.6	.61	79.1	34.7	55.4
36	3/8	1	.0203	5.0	49.68	1.42	33.8	33.6	23.7	.59	79.1	30.6	49.0
37	3/8	1	.0486	12.0	49.68	1.56	71.2	29.5	18.9	.57	78.1	27.2	43.5
38	3/8	1	.0495	12.0	49.68	1.56	72.0	29.3	18.8	.57	78.1	27.1	43.3
39	3/8	1	.0488	12.0	49.68	1.56	74.3	30.7	19.7	.57	78.1	28.3	45.3
40	3/8	1	.0485	12.0	49.68	1.56	71.8	29.9	19.2	.57	78.1	27.6	44.2
41	3/8	1	.0239	6.0	49.68	1.61	35.4	29.8	18.5	.56	68.8	31.3	50.0
						$k \approx 0.74$							
42	3/16	2	0.0243	12.0	49.63	0.403	40.5	33.5	83.2	0.74	70.8	34.0	41.9
43	3/16	2	.0213	12.0	49.63	.290	33.9	32.1	110.6	.77	75.8	30.5	37.5
44	3/16	2	.0214	12.0	49.63	.290	30.6	28.8	99.2	.76	75.8	27.1	33.4
45	1/4	2	.0241	12.0	49.63	.403	35.4	29.5	73.2	.73	68.8	31.0	41.3
46	1/4	1	.0241	12.0	49.63	.403	38.3	32.0	79.3	.74	68.8	33.4	44.6
47	5/16	1	.0243	12.0	49.63	.403	37.1	31.0	76.9	.74	70.8	31.5	45.8
48	3/8	1	.0234	12.0	49.63	.403	32.8	28.2	70.0	.73	70.8	28.7	45.9

[a] Actual tensile strength of material.

[b] Stresses corrected to σ_{ult} = 72 ksi.

[c] These specimens had heavy stiffeners dividing them into panels 1 inch by 5 inches. (See fig. 1, reference 1.)
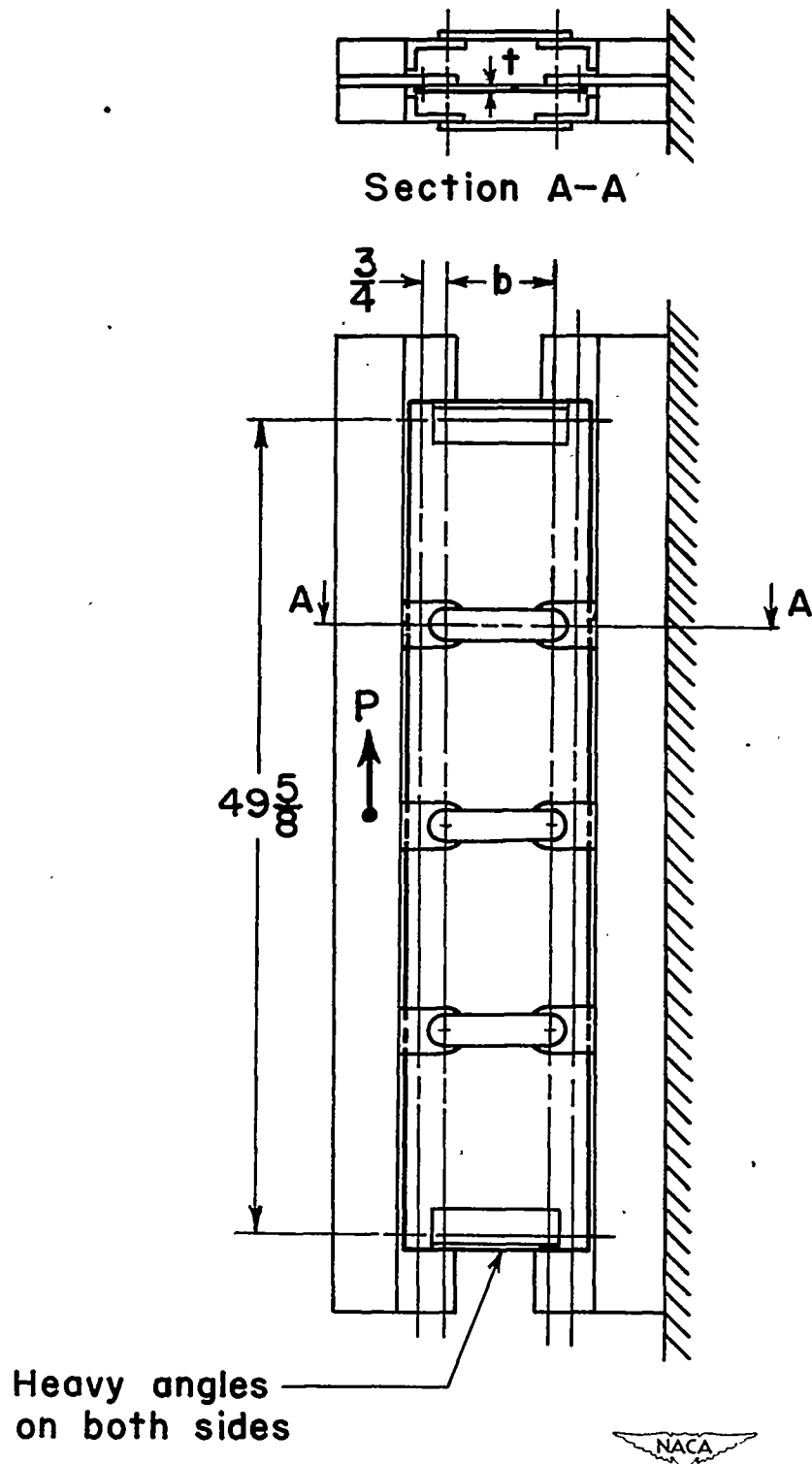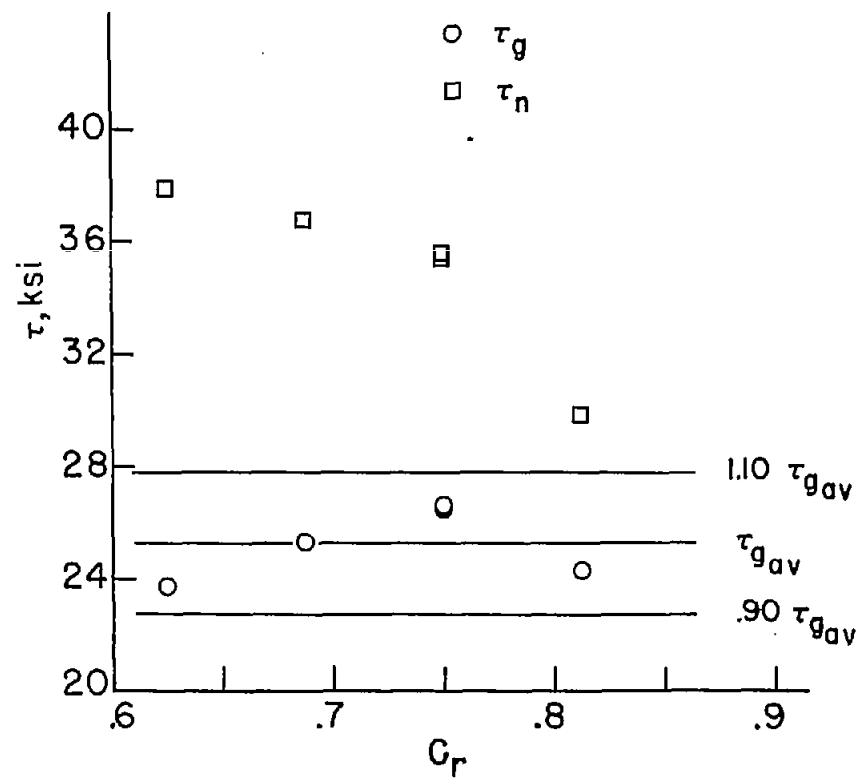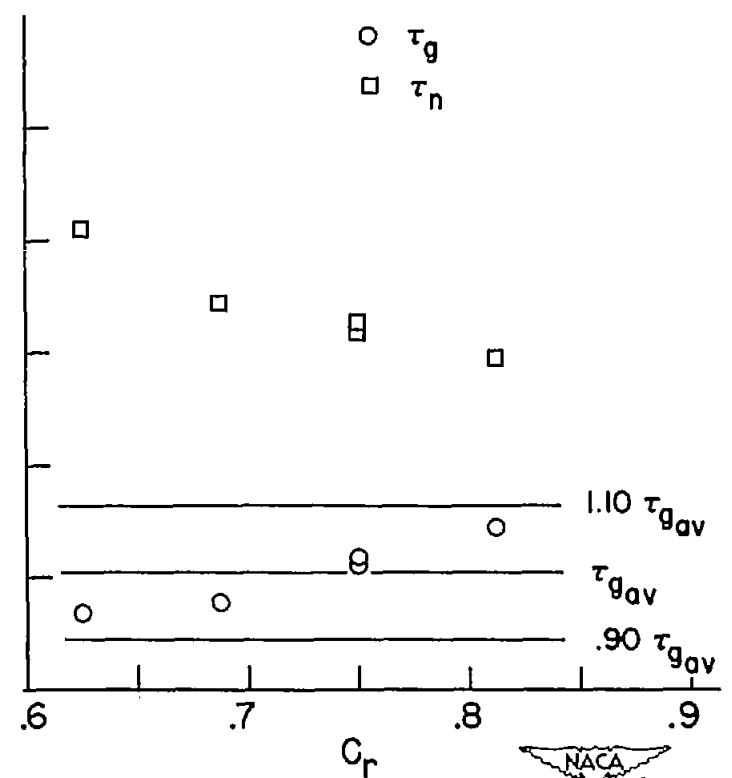
Section A-A

$\frac{3}{4}$ b

$49\frac{5}{8}$
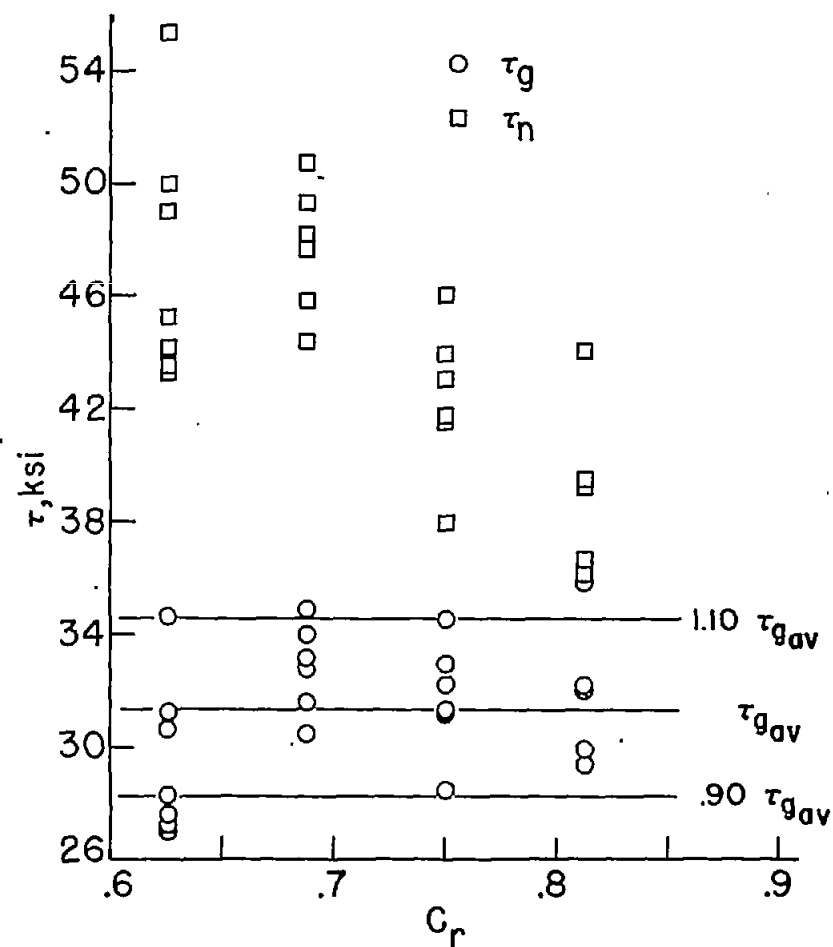
P

Heavy angles
on both sides

Figure I.— Rectangular test frame.

(a) k ≈ 0.55.

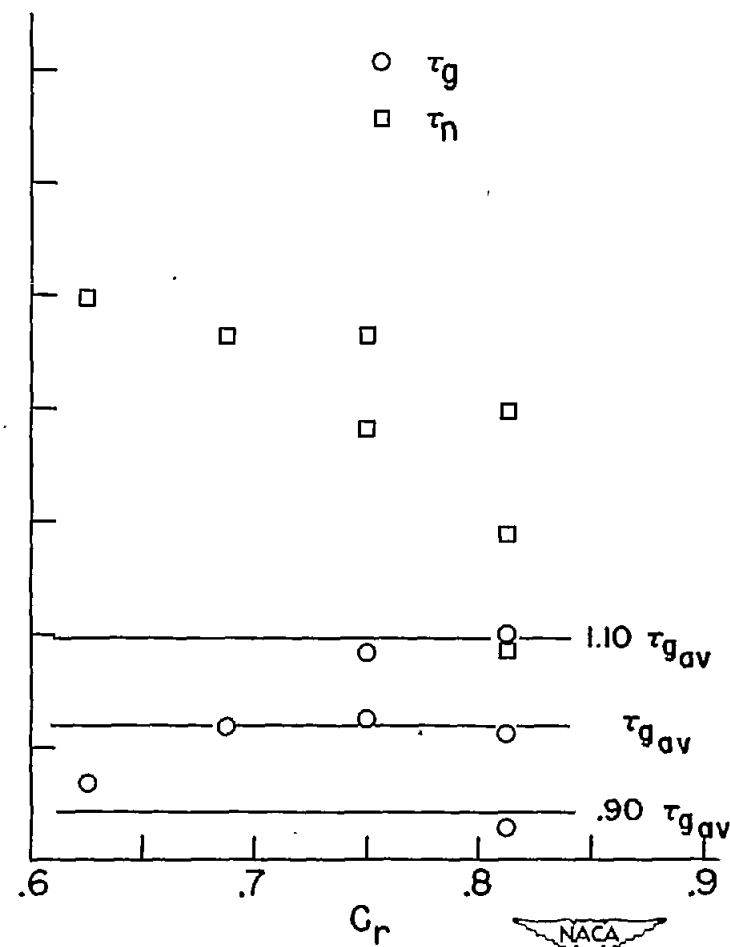(b) k ≈ 0.72.

Figure 2.— Ultimate shear stresses in 24S-T aluminum-alloy webs. (All stresses corrected to $\sigma_{ult} = 62$ ksi .)
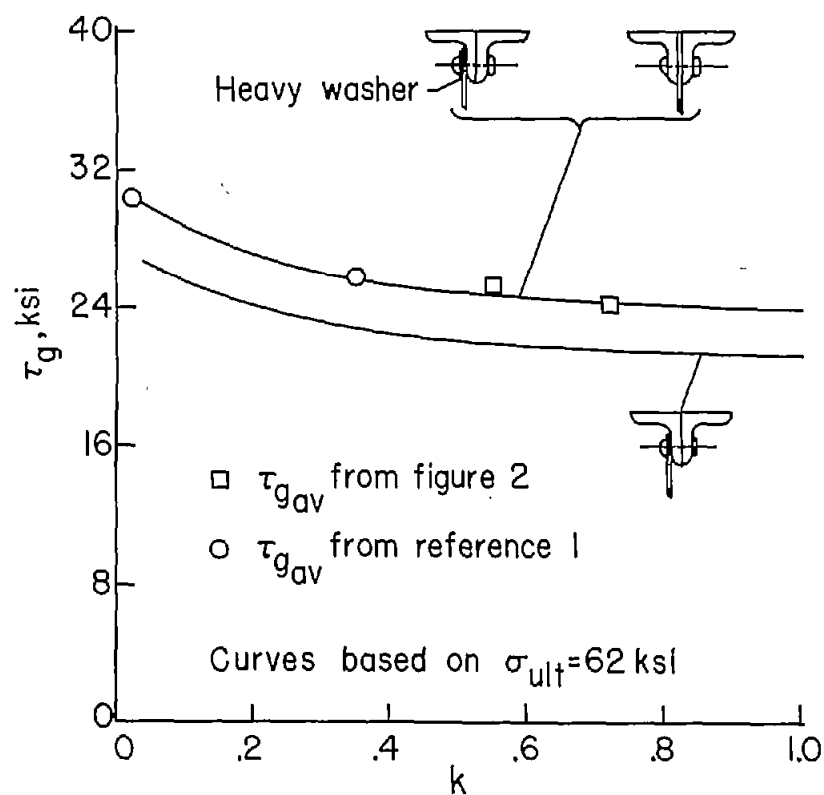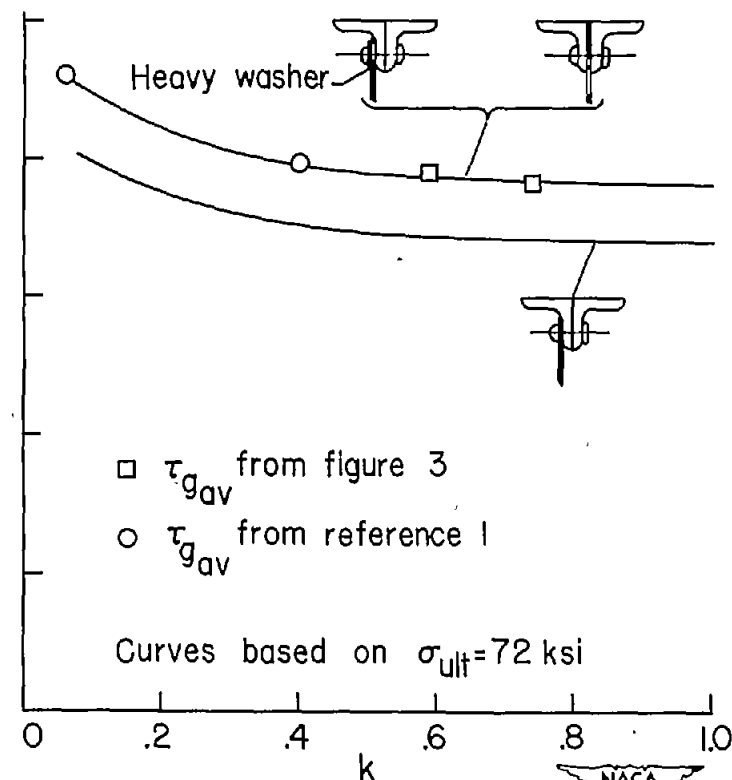
(a) k ≈ 0.59.

(b) k ≈ 0.74.

Figure 3.- Ultimate shear stresses in Alclad 75S-T aluminum-alloy webs. (All stresses corrected to $\sigma_{ult} = 72$ ksi.)

(a) 24S-T aluminum alloy.

(b) Alclad 75 S-T aluminum alloy.

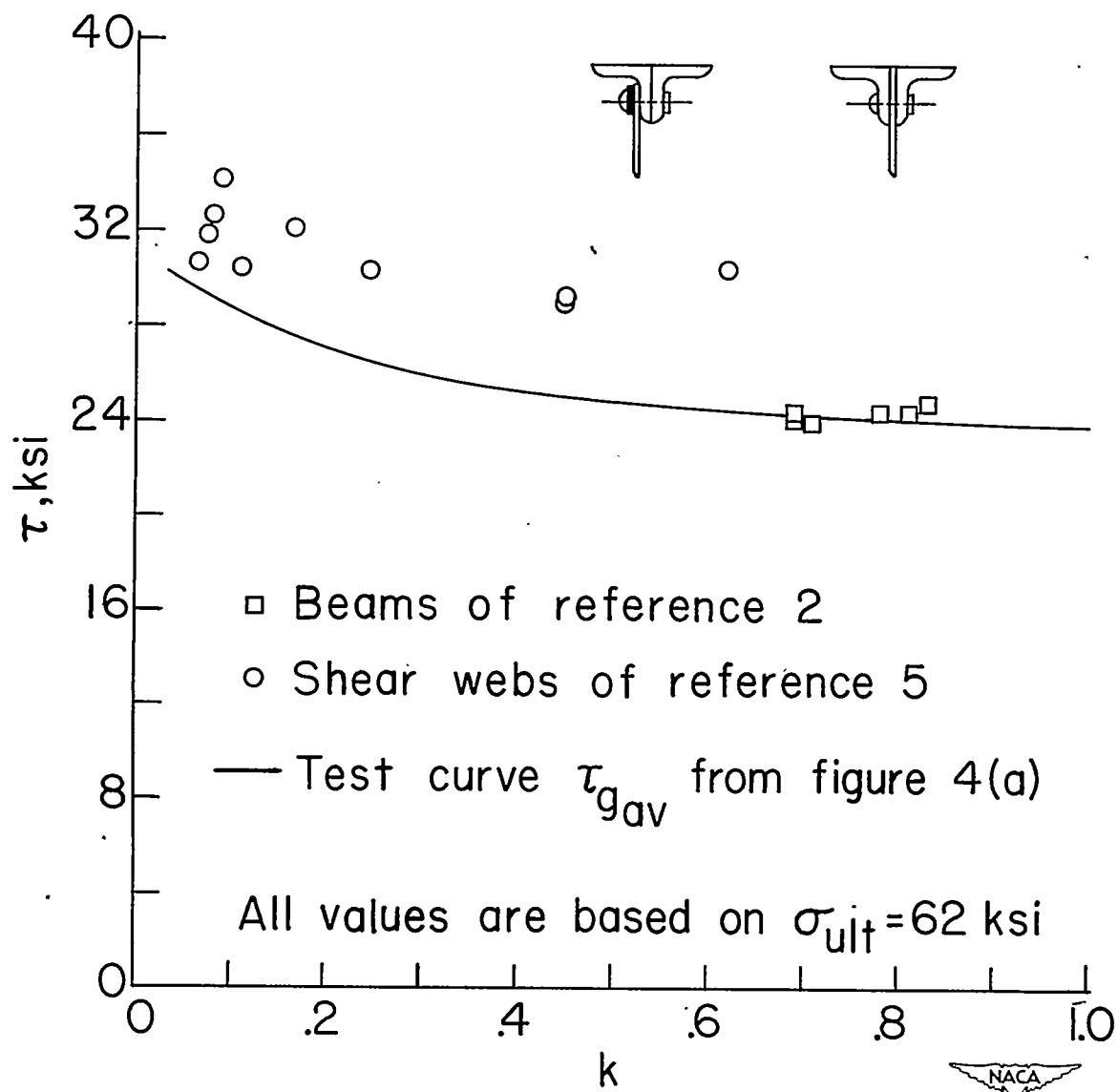Figure 4.- Average ultimate shear stresses in the gross section.

Figure 5.— Shear stresses at failure in 24S-T aluminum alloy.